ELECTRIC VEHICLES WITH V2G

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University of Delaware and
Mid-Atlantic Grid Interactive Cars Consortium

Presented at
DE Economic Development Workgroup
30 July 2008

OLD SCHOOL EVS

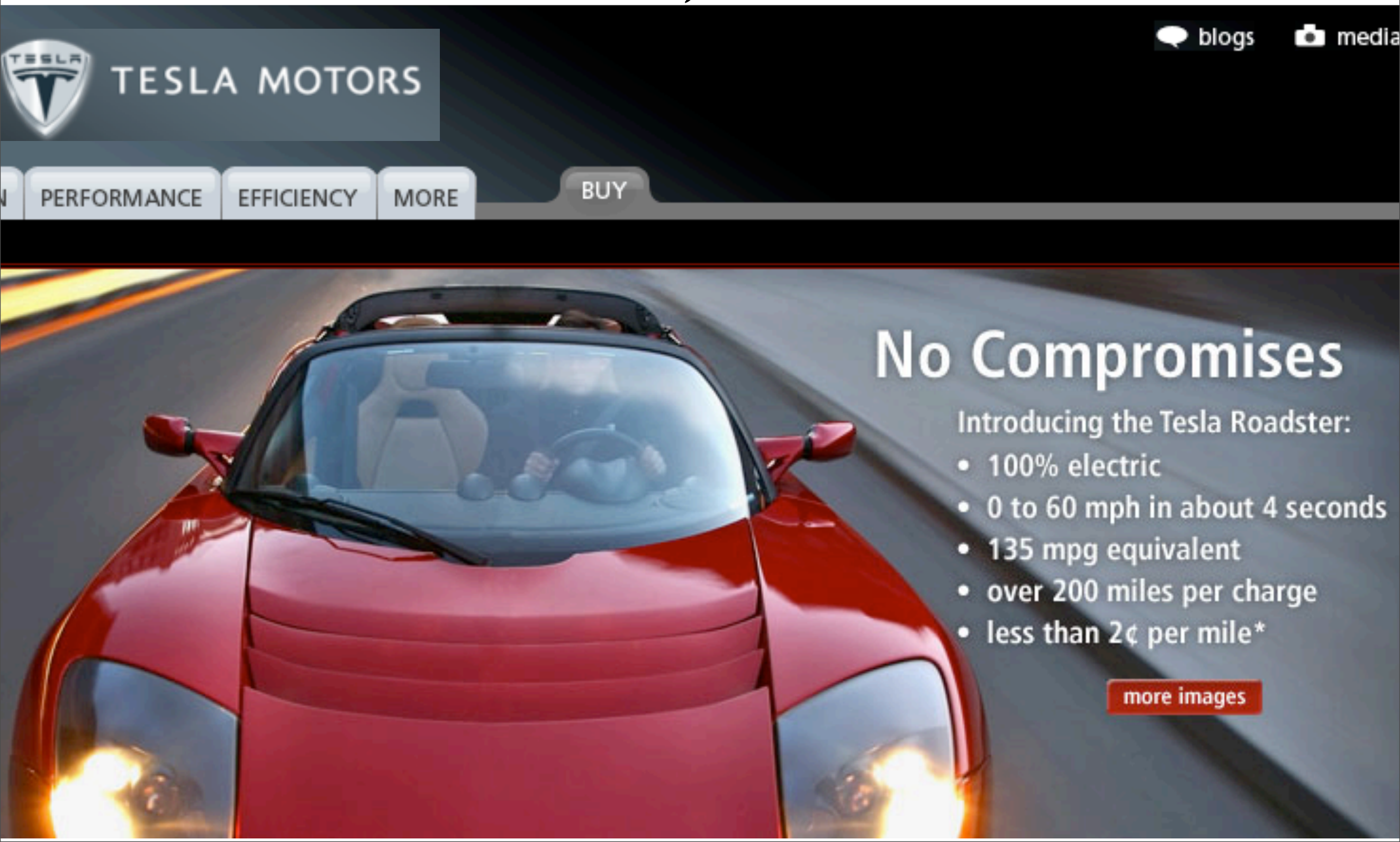
- NiMH or (gasp!) Pb-acid
- 60 miles range, high range anxiety
- Oh-hum performance
- Special (=expensive) charging stations, slow charge
- Electrially, it's a load, and a dumb load
  - pull power upon plug-in, quit when charged
  - low power: 110v 15 amp, 1.5 kW

NEW SCHOOL EVS

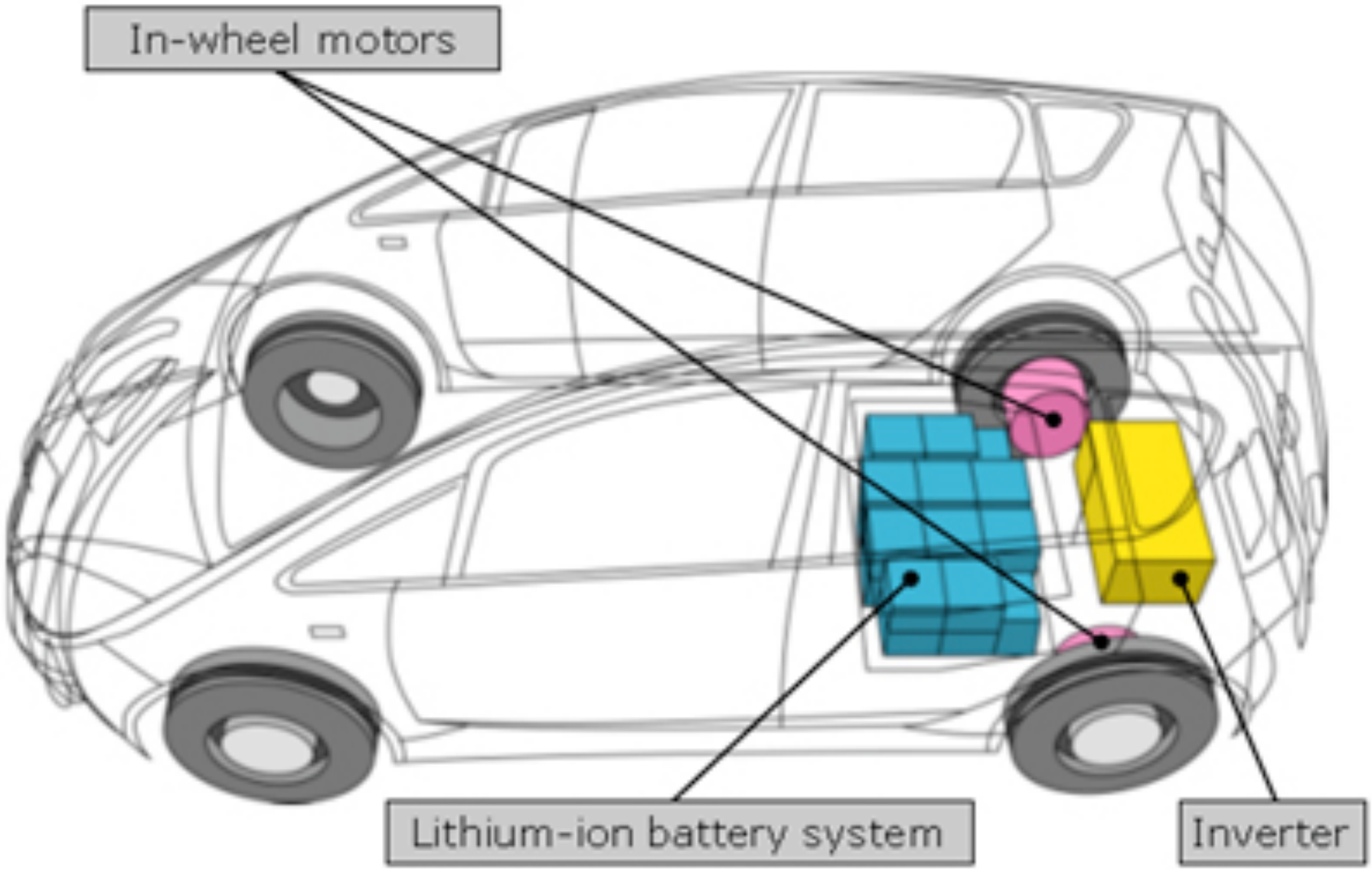
- Lithium chemistries, induction motor
- 130 to 230 miles range (25 - 50 kWh)
- Integrated charger, 14 - 19 kW
- Performance much better than a gas burner
- Typical daily driving uses 1/3 to 1/2 of charge
- Typical recharge < 1 hour; full charge 2-3 hours
- Intelligent interaction with grid likely

Tesla Roadster

“Burn Rubber, not Gasoline”



Mitsubishi Colt platform



In-wheel motor

13 kWh Li-ion, 2 x 20kW in-wheel motors;
developing 50 kW in-wheel motor

eBox

Urban Utility Vehicle

Spacious, efficient, comfortable, unique, sporty, versatile, zero emission,

Electric.

Vehicle Performance

Range	140 – 180 miles
Acceleration	0 to 60 ~ 7 secs
Top Speed	95 mph
Charge rate	30 minutes for 20 – 50 miles
Full Charge	2 hrs (fast), 5 hrs (normal)

eBox

Electric Propulsion

Drive system	120 kW, 220 Nm, 13,000 rpm Regenerative braking
Battery	Li Ion, 35 kWh, 650 lb
Charger	Onboard, plug in anywhere, Up to 20 kW
Vehicle to grid (V2G)	Bi-directional grid interface

Features

Seats	5			
Equipment	Air conditioning	std	Navigation system	opt
	Alloy wheels	opt	Power brakes	std
	Cruise control	std	Power steering	std
	Electric heater	std	Power windows, locks, mirrors	std
	Leather	opt	Traction control	std

* specifications subject to change

eBox

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FUEL ECONOMICS

- Gasoline $4/gallon to ??
- Electricity 75¢/gallon
- But today, battery cost over life (amortized) more than makes up the difference.
- Long-term battery cost $200/kWh, so a car with 150 mile range @ 4mi/kWh would have battery cost of $7,500 ... about cost of engine, fuel and exhaust

AUTOMOTIVE BATTERIES

- 6 million cars and light trucks made in US, even at low 2008 rates
- if 1/2 were electric, at $7K retail, a $42B market in US
- Major area of R&D; electrochemistry and nanostructures

FUTURE BATTERIES?

LETTERS

High-performance lithium battery anodes using silicon nanowires

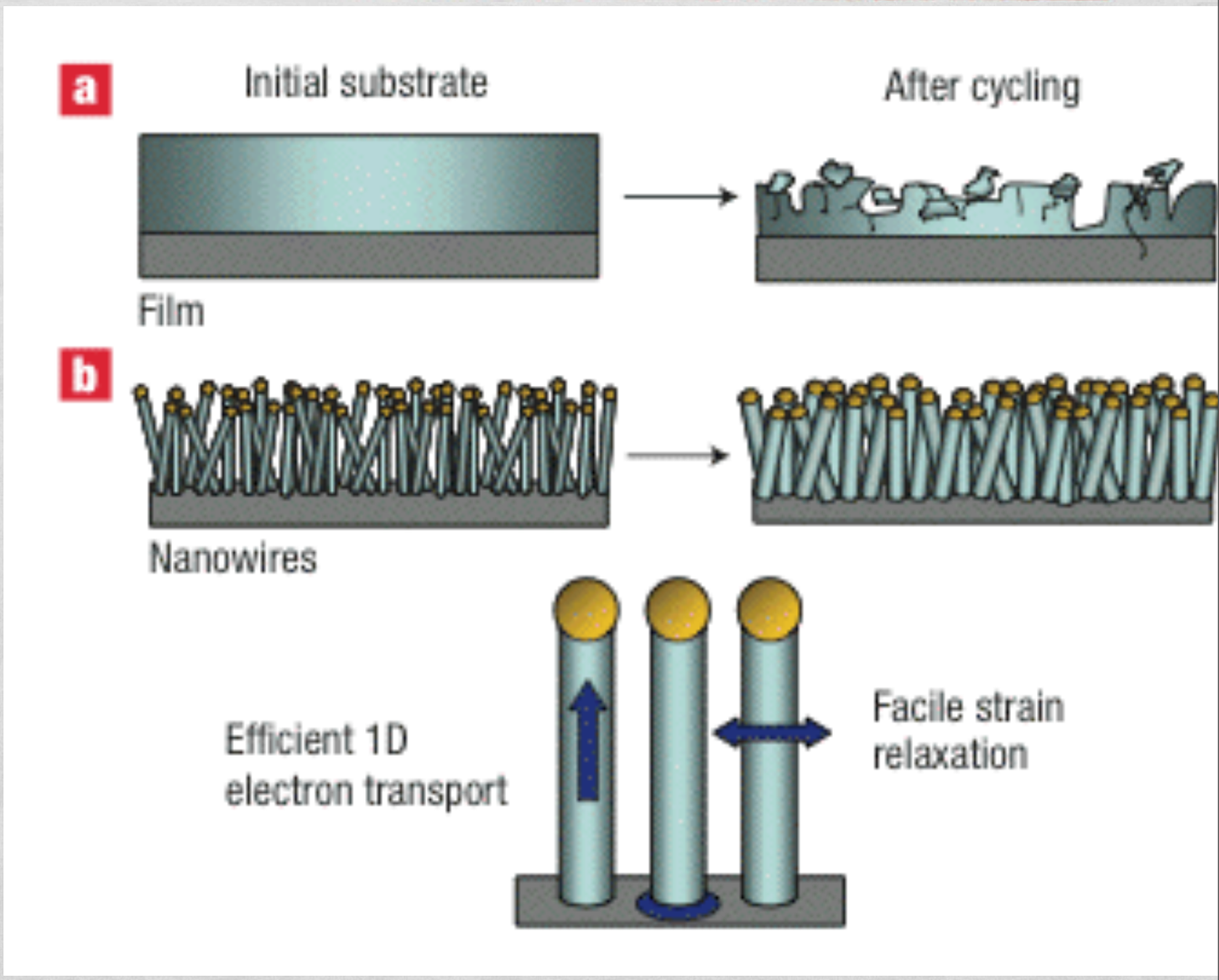
CANDACE K. CHAN[1], HAILIN PENG[2], GAO LIU[3], KEVIN McILWRATH[4], XIAO FENG ZHANG[4], ROBERT A. HUGGINS[2] AND YI CUI[2]*

Published online: 16 December 2007; doi:10.1038/nnano.2007.411

- Very large performance improvement on anode using Si and nanostructure
- If cathode could similarly be improved, that would be a 300 kW battery, car range of 1,000 miles per charge

SILICON CHANGES EVERYTHING (AGAIN)

- Li battery with Si anode "low discharge potential and the highest known theoretical charge capacity"
- Si nanowires, unlike Si film, expand without breaking
- Lab result: 7x more energy stored than graphite anode -- same size and weight!



TRANSITION

- Problem: Batteries temporarily expensive
- Old school solution: Plug-in hybrids
- New school solutions: 4+ business models:
  - Low-range (<100 mi) niche, small EVs (TBD)
  - Bundle battery and electricity, sell miles (Project Better Place)
  - Porsche 911 market, but cooler (Tesla)
  - Costly sedan, sell electric services (MAGICC)

MID-ATLANTIC GRID-INTERACTIVE CAR CONSORTIUM (MAGICC)

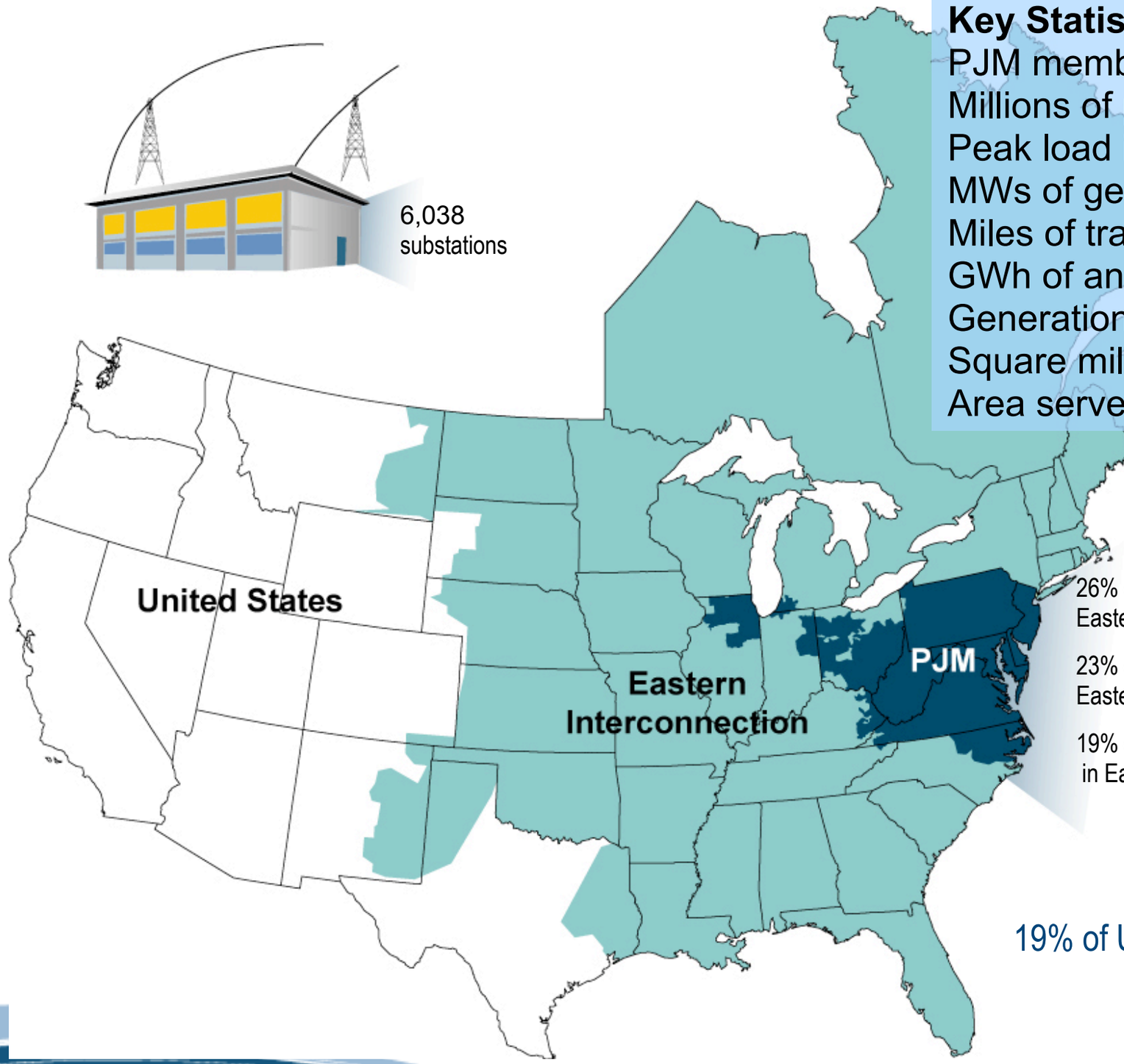
- Partners
  - University of Delaware
  - PHI: Delmarva Power, Atlantic Electric, PEPCO, etc
  - PJM Interconnect
  - AC Propulsion
  - ACUA
  - Comverge
- Observers
  - Tesla Motors
  - Google.org
  - State of Delaware (DEDO, PSC, Energy Office)
  - anon
  - Others pending

http://www.magicconsortium.org

6,038
substations

Key Statistics

PJM member companies	470+
Millions of people served	51
Peak load in megawatts	144,796
MWs of generating capacity	165,303
Miles of transmission lines	56,070
GWh of annual energy	728,000
Generation sources	1,271
Square miles of territory	164,260
Area served	13 states + DC



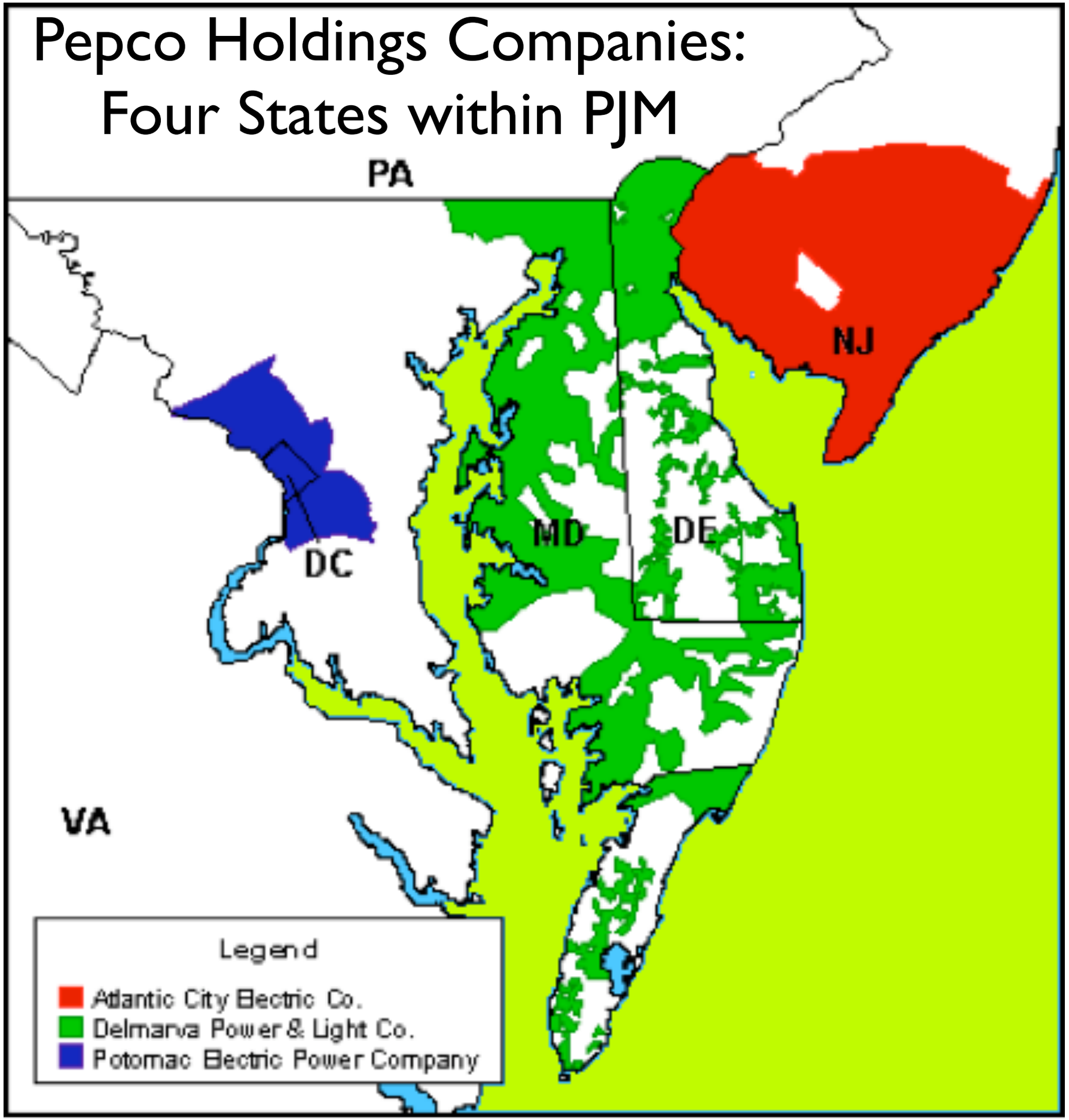
26% of generation in
Eastern Interconnection

23% of load in
Eastern Interconnection

19% of transmission assets
in Eastern Interconnection

19% of U.S. GDP produced in PJM

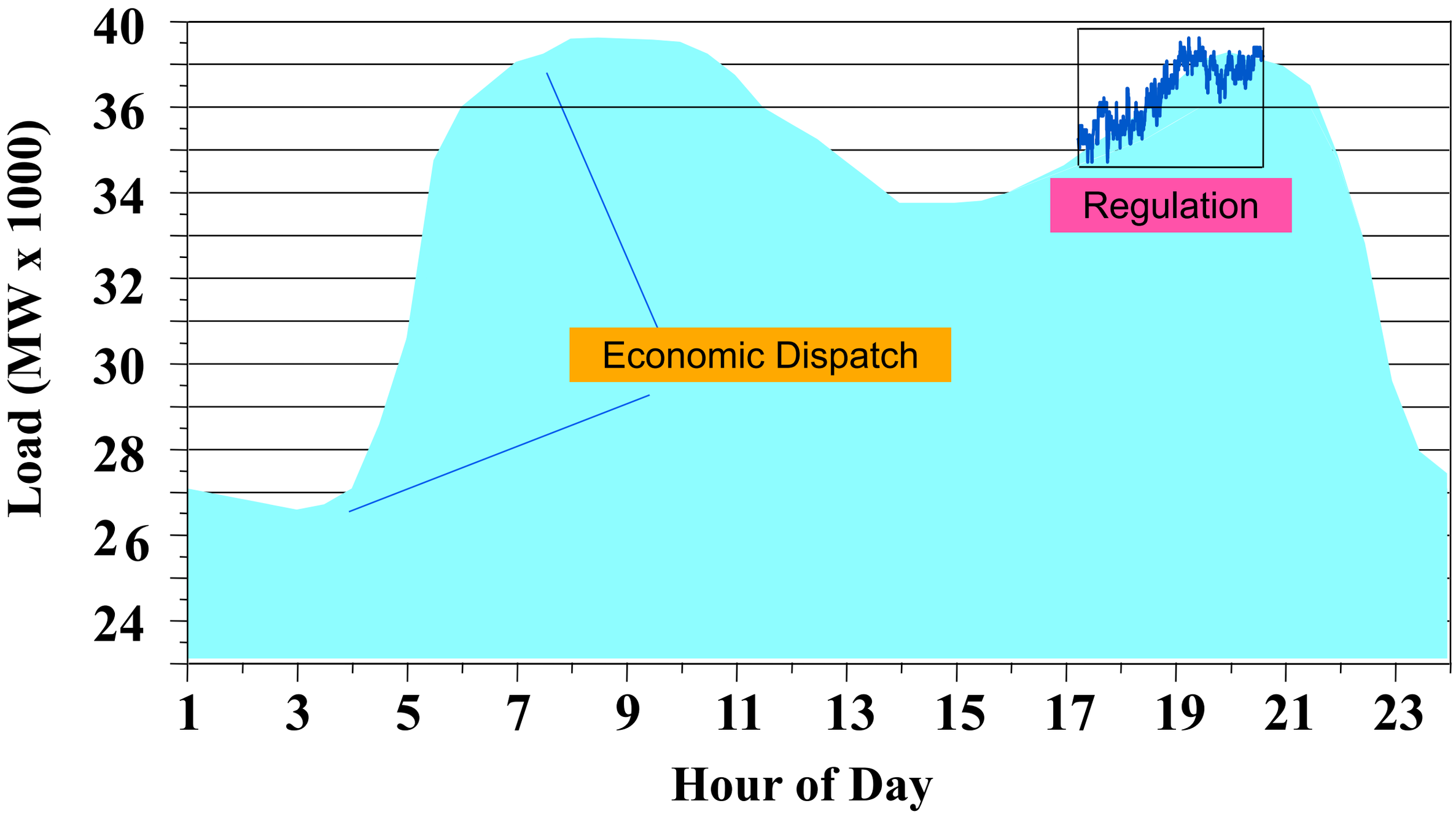
Pepco Holdings Companies: Four States within PJM



EARLY TARGET MARKETS

- Initial, high-value markets, are A/S
  - Regulation
  - Spinning reserves
- Later, larger markets with lower value per kW
  - Defer upgrades to distribution feeders, transformers
  - Peak load reduction, valley filling
  - Power factor correction ... etc. etc.

Regulation vs Economic Dispatch



Peak load is once (or twice) a day. Regulation is 24/7.

WHAT THE ISO SEES

scs01awp - Terminal Server Client

Real Time

Operations | Generation | Scheduling | Transmission | Forecast | Energy Data | Trading | Simulation | System | Help | 12-Oct-07 | 3:10:39 PM

E - Al 2 | E - Al 3 | G - Al 1 | G - Al 2 | W - Al 1 | W - Al 2 | Tools | Displays | Communications | Logon Logoff | Silence | Audio Inhibit

<Realtime (RT)> - Runtime Explorer

File View Tools Help

SE_RTS_01 | CFE View | OPC View | ICCP UI | Marker Summary | All Marker Types

Substation View - Network/Substations/V2GCAR1

- Sub CFE CDC2 A
- Sub CFE D
- Sub CFE DNP30 A
- Sub CFE E
- Sub CFE F
- Sub CFE TG800 A
- Sub CFE TG800 B
- Sub CFE TG8979 A
- Sub CFE TG8979 A_Listen
- Sub D
- Sub E
- SUNBURY
- TEST_EXTERNAL_INTERNET_SUB
- TEST_INTERNAL_INTERNET_SUB
- TEST_PJMNET_SUB
- TEST_WIRELESS_INTERNET_SUB
- THOMPSCR
- V2GCAR1
- VAUGHN
- Warren
- WPSENERG
- Substations 20kV
- Substations DMS
- Substations LC
- P1

Name	Type	Value	Source/Quality
/BATTERY CHARGE STATE	AnalogMeasurem...	60	Telemetered
/COMMUNICATIONS	DigitalMeasurement	Normal	Calculated
/LINE AMPS	AnalogMeasurem...	12	Telemetered
/LINE CHARGE CAPACITY KILOWATTS	AnalogMeasurem...	4.8	Telemetered
/LINE CONNECTION STATUS	DigitalMeasurement	Connected	Telemetered
/LINE DISCHARGE CAPACITY KILOWATTS	AnalogMeasurem...	4.8	Telemetered
/LINE KILOWATTS	AnalogMeasurem...	-3.3	Telemetered
/LINE POWER FACTOR	AnalogMeasurem...	0.5	Telemetered
/LINE VOLTAGE	AnalogMeasurem...	240	Telemetered
/PJM REGULATION SIGNAL	AnalogMeasurem...	-496.0396	Calculated
/PJM REGULATION SIGNAL FEEDBACK	AnalogMeasurem...	-523	Telemetered
/PJM TOTAL REGULATION	AnalogMeasurem...	807.4	Calculated
/PJM TOTAL REGULATION FEEDBACK	AnalogMeasurem...	807.4	Telemetered

OPC View | ICCP UI | Marker Summary | All Marker Types

s/V2GCAR1

	Name	Type	Value	Source/C
	/BATTERY CHARGE STATE	AnalogMeasurem...	60	Telemete
	/COMMUNICATIONS	DigitalMeasurement	Normal	Calculate
	/LINE AMPS	AnalogMeasurem...	12	Telemete
	/LINE CHARGE CAPACITY KILOWATTS	AnalogMeasurem...	4.8	Telemete
	/LINE CONNECTION STATUS	DigitalMeasurement	Connected	Telemete
	/LINE DISCHARGE CAPACITY KILOWATTS	AnalogMeasurem...	4.8	Telemete
	/LINE KILOWATTS	AnalogMeasurem...	-3.3	Telemete
	/LINE POWER FACTOR	AnalogMeasurem...	0.5	Telemete
	/LINE VOLTAGE	AnalogMeasurem...	240	Telemete
	/PJM REGULATION SIGNAL	AnalogMeasurem...	-496.0396	Calculate
	/PJM REGULATION SIGNAL FEEDBACK	AnalogMeasurem...	-523	Telemete
	/PJM TOTAL REGULATION	AnalogMeasurem...	807.4	Calculate
	/PJM TOTAL REGULATION FEEDBACK	AnalogMeasurem...	807.4	Telemete


pjm

Average Annual Market Clearing Prices: Regulation

	Regulation ($/MW-h)		
	2004	**2005**	**2006**
PJM	$42.75	$49.73	$32.69
RTO-NE	$28.92	$30.22	$24.02
NY ISO	$22.59	$39.21	$51.26
ERCOT	$22.66	$38.07	n/a
CAISO	$29.00	n/a	$36.04

WHO WILL PROVE THIS?

- Initial demonstrations do not pay for themselves, until high power vehicles under $40,000/vehicle (currently $70K cost, long-term aprox $5K premium)
- OEMs will not build or invest in vehicles appropriate for high-value electrical uses, this will probably fall on the electric sector and/or government
- MAGICC is planning demonstration of 1 MW level (200+ vehicles at 15+ kW each); some policy support needed

SEVERAL BUSINESS OPPORTUNITIES

- Build (via conversion) electric cars with V2G in quantities of 100 - 1,000 per year (200 gets one reliable MW; now build rate is 1/month in CA)
- Source some components for above
- Develop software for complex power transactions and predictive model of vehicle
- Develop V2G "aggregator" business(es) that buy kW and sell MW

POSSIBLE POLICIES

- Cost reductions for early electric vehicles
- R&D Incentives
- Install plugs at stopover points (SAE standard in draft final form)
- .....

SUMMARY

- EVs will be the high performance vehicles, fun to drive, plus marketing advantage of "no gasoline"
- MAGICC design: car learns driver needs and sells services to the grid -- "the grid interactive car"
- Grid communication demonstrated at individual vehicle level, next step is 1 MW power plant with aggregation of 200+ vehicles and smart dispatch
- Business opportunities in battery R&D, then materials, components vehicle assembly, V2G "aggregator", plug installations

MORE INFORMATION

- Magic Consortium
  - www.magicconsortium.org

- V2G research
  - www.udel.edu/V2G